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Hazard & operability study and determining safety integrity level on sulfur furnace unit: A case study in fertilizer industry

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Abstract

In the process production, it is possible that some risks may be happen and potentially causing hazard. Therefore, it will lead to a failure to achieve the production target. Hazard & Operating Study (HAZOPS) of sulphur furnace are done in this research. Here, the nodes used are sulphur furnace, waste heat boiler, and steam superheater. From the analysis, it obtained 11 instruments attached on those three nodes with the highest hazard potential reaches extreme level based on AS/NZS 4360:2004 standard, while in standard of the factory it reaches a high level. Both of them are in low temperature sulphur furnace and high temperature sulphur furnace deviation. At the Safety Integrity Level (SIL) determination, it obtained 1st level of SIL on installed SIS in node sulphur furnace with a total of PFD 0,021 and RRF 48,3. Meanwhile, SIL 1 in waste heat boiler has a total value of Probability Failure of Demand (PFD) 0.0184 and Risk Reduction Factor (RRF) of 54.32. While in the last node, steam superheater, the SIS is not installed.

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1. Introduction

There are few possible risks that can be happen in the production process. Risks can lead to the failure of reaching the goal of production, or even can lead to a hazard. Therefore, a study is needed to understand what kind

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of hazard that potentially happen in the plant, and also the solution to prevent the hazard in the production process system by doing a risk management that cover Safety Instrumented System. One of the units that have an important role on the production process of sulphuric acid in 3rd plant of PT Petrokimia Gresik is sulphur furnace. Sulphur furnace has a function to combust molten sulphur so it results SO_2. In the operation process, there are some potential hazards that can be happen. So, a HAZOP study is needed to understand more about the potential hazard [7], and then a SIL calculation needs to be done to know the safety level of the operating SIS (Safety Instrumented System) [2]

2. Material and methods

2.1 Process study

Process study is done to understand the process happened in sulphur furnace, including the material used in the process. The study is done by using references that are obtained from data planning, operating, controlling, and maintaining of sulphur furnace in 3rd plant of PT Petrokimia Gresik[3].

2.2 Data collecting

The data needed in this research are historical data related to the process done in the sulphur furnace of PT Petrokimia Gresik. The data are in the form of flow chart diagram, Piping and Instrumentation Diagram (P&ID), and data maintenance of tools from each component that are related to the process done in sulphur furnace. The data are used for identifying the hazard potential and measure the rate of SIL.

2.3 Hazard identification

The method used to identify the hazard [7] is called HAZOPS (Hazard and Operability Study). This method is consists of some steps as shown below [9]:

- Determine the node based on Piping and Instrumentation Diagram (P&ID) of sulphur furnace. The node is determined based on the main and supporting components of sulphur furnace. The number of nodes depends on the complexity of the observed process unit
- Determine the components in every node that consists of control system and security system
- Determine the deviation from each node component supported by the use of guide words to characterize the type of deviation happened in each of the component. The deviation itself is obtained based on control chart of the process that has been done in a whole month
- Do the analysis of the cause of the deviation in each of the node component and the security system worked in the node.

2.4 Risk estimation

Risk estimation is done by analyzing the two components of the probability and consistent, namely:

• Likelihood
Likelihood is the probability of a risk that can occur in a component in a given period [1]. Likelihood estimation is calculated by using the data report diaries control room [4][5]. From the data failure of each component at a certain period of time, the value of Mean Time to Failure (MTTF) as the average time that a component failure is determined. Likelihood value is obtained from the comparison between the amount of the daily operations of the MTTF value overall production period, in one day running the production company for 24 hours. Furthermore, the likelihood is determined level. The likelihood calculation follows the following equation:

$$Likelihood = \frac{61320}{MTTF} \quad (1)$$

As for the components that are not available in the data maintenance, MTTF value is calculated from the data failure rate contained in the database Offshore Reliability Data. The equation used is as following [10]

$$\text{MTTF} = \frac{1}{Failure\ Rate\ (\lambda)} \quad (2)$$

• Consequences
Consequences are determined based on the reading of the transmitter and indicator deviation [8] from the average value observed at the level of control achieved by the data limitv[8]. Overview Consequences associated with the level of damage to components, effects on humans and the level of costs incurred due to the danger posed with lost due loose cost of production due to the process. Referenced standard is the standard Australian / New Zealand [1].

2.5 Risk analysis

Risk Analysis of the risk carried out by combining the likelihood and Consequences that have been obtained in the estimation stage. The combination is obtained by using a risk matrix which refers to the standard AS / NZS 4360: 2004 standards [1] adequate for PT Petrokimia Gresik[3] shown in Table 1.

Table 1. Risk matrix standard [1]

Likelihood	**Consequences**				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A(Almost Certain)	H	H	E	E	E
B (Likely)	M	H	H	E	E
C (Moderate)	L	M	H	E	E
D (Unlikely)	L	L	M	H	E
E (Rare)	L	L	M	H	H

2.6 Safety Integrity Level (SIL) analysis

Analysis of safety integrity level is done to look at a system lies in a certain security level. SIL is determined by finding the average PFD value adjusted by the SIL table shown in Table 2 [6].

Table 2. Table safety integrity level [6]

Safety Integrity Level	*Probability of Failure on Demand*	*Risk Reduction Factor*
4	0,0001 – 0,00001	100.000-10.000
3	0,001 – 0,0001	10.000-1000
2	0,01 – 0,001	1000-100
1	0,1 – 0,01	100-10

3. Analysis and discussion

Basically, SO_2 generation unit has function to generate SO_2 gas from the combustion of molten sulphur with O_2 gas from dry air. The combustion is done in the furnace. The main instrument in SO_2 generation process is sulphur furnace (B-1101), SO_2 generation unit consists of three main parts such as sulphur furnace (B-1101), waste heat boiler (B-1104), and steam superheater (E-1102). Sulphur furnace is used for producing SO_2 gas, while waste heat boiler and steam superheater are used for producing superheated steam that has a function as factory utility

3.1 HAZOPS analysis

In sulphur furnace node, there is a combustion of molten sulphur and dry air, so there are five parameters process observed in the control room such as flow indicator instrument (FI-1103), pressure indicator instrument (PI-2002.9), flow recorder instrument (FR-1301), pressure indicator (PI-1007.2), and temperature recorder instrument (TR-1101).

To see the stability of the process, standard deviation value is needed from each instrument, compared to the mean from each instrument. Based on the control chart, the guide word and standard deviation [8] analysis are done and resulting a data below in Table 3.

Table 3. Guideword and node sulphur furnace deviation

No.	Component	Guideword	Deviation
1	Flow Indicator (FI-1103)	Less	Less Flow
2	Temperature Recorder (TR-1101)	Low	Low Temperature
		High	High Temperature
3	Pressure Indicator (PI-1001.9)	Low	Low Pressure
4	Pressure Indicator (PI-1007.2)	Low	Low Pressure
5	Flow Recorder (FR-1301)	Less	Less Flow

On the waste heat boiler, there is a heat transfer between SO_2 gas as a result of the combustion in the furnace, and condensed water from boiler feed water system to produce saturated steam. Some parameters that observed in the control room are level recorder (LR-1102), flow indicator (FI-1102), pressure recorder (PR-1102), and temperature indicator (TI-1002.3). The deviation analysis is shown in the Table 4

Table 4. Guideword and node waste heat boiler deviation

No.	Instrument	Guideword	Deviation
1	Level Recorder (LR-1102)	Less	Less Level
		More	More Level
2	Flow Indicator (FI-1102)	Less	Less Flow
3	Pressure Recorder (PR-1102)	Low	Low Pressure
4	Temperature Indicator (TI-1002.3)	Low	Low Temperature
		High	High Temperature

Steam super heater in SO_2 generation unit is used for increasing the temperature from saturated steam, as an output of waste heat boiler, to superheated steam. The process happened in the steam super heater is same with the process happened in waste heat boiler. There happens a heat transfer between SO2 gas, the output of waste heat boiler that has a high temperature, and saturated steam as the output of waste heat boiler so it results a superheated steam. Some parameters observed in the control room are pressure indicator (PI-1103), and temperature recorder (TR-1103). The deviation analysis is shown in Table 5.

Table. 5. Guideword and node steam superheater deviation

No.	Component	Guideword	Deviation
1	Pressure Indicator (PI-1103)	Low	Low Pressure
2	Temperature Recorder (TR-1103)	Low	Low Temperature
		High	High Temperature

After it is resulting guideword and deviation analysis from each instrument in every component, then HAZOPS (Hazard and Operability Study) analysis [7][9].

3.2 SIL Analysis

In sulphur furnace node, there is SIS that has a function as protection system of fuel system. Fuel system is used in start-up furnace for increasing the temperature of the furnace using combustion with gas fuel.
The component in SIS fuel system furnace consists of pressure switch (PS-012) as sensor, relay as logic solver, and valve as the final element. The calculation of PFD is shown below in the Table 6.

Table 6. SIL fuel system furnace determination

Component	Failure Rate (λ)	TI (hours)	PFD_{avg}	PFD_{Tot}	RRF	SIL
Sensor (PS012)	3,6 x10^{-6}	8760	0.0158	0.02 07	48.2 686	1
Logic solver (*Relay*)	0,6 x10^{-6}	8760	0.0026			
Final Element (*Valve*)	0.53 x10^{-6}	8760	0.0023			

In waste heat boiler, there is SIS that used as protection system for steam drum. SIS is working if steam drum is in low level. When the steam drum is in low level, the level switch will send the signal to relay as the logic solver to turn off the blower C-1301/02. The calculation of PFD is shown below in Table 7.

Table. 7. SIL waste heat boiler determination

Component	Failure Rate (λ)	TI (hours)	PFD_{avg}	PFD_{Tot}	RRF	SIL
Sensor (LSLL1101)	3,6 x10^{-6}	8760	0.0158	0.01 84	54.3 2	1
Logic solver (*Relay*)	0,6 x10^{-6}	8760	0.0026			
Final Element (*Blower* C1301/02)	0.6 x10^{-6}	8760	1.38 x 10^{-5}			

After calculating the PFD, it is resulted that all operating SIS (3) has the level SIL of 1.

4. Conclusion

From the HAZOP Analysis there are some conclusions that can be obtained. Such as, after the hazard identification has been done, it can be seen that the component with the highest risk is on the sulphur furnace node. Based on the AS/NZS 4360:2004 Standard, the high temperature and low temperature deviation reached the extreme level. Furthermore, based on factory standard in PT. Petrokimia Gresik, the high temperature and low temperature also reached the extreme level. So from both standards it can be concluded that it reached the highest risk level. Meanwhile, from SIL calculation in sulphur furnace node, it obtained the 1st level of SIL, with PFD value of 0.021

and RRF value of 48.3. In waste heat boiler node, it has the 1st level of SIL in SIS with PFD value of 0.018, and RRF value of 54.3. So, the risk of each component that is on the 1st level of SIL has been considered safe.

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